

PLASTER REINFORCEMENT WITH FIBERS BY MINERAL WOOL OBTAINED FROM THE RECYCLE OF CONSTRUCTION AND DEMOLITION WASTE

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ABSTRACT

The use of mineral wool is becoming more widespread due to increased acoustic and thermal demands of Spanish Technical Building Code. This increase affects both in rehabilitation and new construction projects. Therefore, waste generation of this type of insulating material is having more importance.

The main objective of this research is to study the feasibility of recycling fiber obtained from mineral wool of the C&D waste as an alternative material to chopped glass fibers that are currently used as reinforcing elements in the prefabricated plaster.

To achieve this objective, series are made of plaster E-35 additivated with rock wool residue and glass wool residue at different rates of addition. These series are repeated by changing the additive by E fiberglass (length of 25mm) to make a comparative analysis with respect to the series additivated with mineral wool waste. All the series are subjected to the test to determine Shore C surface hardness and also to mechanical testing to determine the compressive and flexural strength.

From the results obtained it is concluded that, with rock wool residue Shore C hardness increases in all the addition percentages, reaching a 12% improvement with respect to the fiberglass, with an addition rate of 2%. However, lower values are obtained for flexural strength for all the percentages of addition. The biggest difference, 50%, appears with the addition rate of 4%. The compression strength test results obtained with the series additivated with rock wool residue are superior to all percentages addition studied. The main difference appears for 3% of addition, in which the series additivated with rock wool residue exceeds 36% of the additivated with fiberglass.

With regard to the series additivated with glass wool residue it can be concluded that the surface hardness improves lineally by around 5% for all percentages addition, with regard to the series additivated with fiberglass. The values of flexural strength are superior to 3% of addition; this improvement reaches to 26% with a rate of 1% of addition. The values obtained in the compression strength test are higher for all percentages of addition, except for the 4%. This improvement reaches the 41% for the percentage of addition of 3%.

As a final conclusion, it can be noted that series additivated with mineral wool from recycling show better results in tests than fibers used as reinforcement plaster nowadays, so it is viable their replacement.

Keywords: mineral wool, recycling, C&D waste, plaster, fibers

1.- Introduction

During the last decade the intense activity in the field of construction has generated large amounts of waste from construction and demolition (C&D waste). In Europe, it has been generated about 890 million tons of C&D waste of average a year, however, only 50% of these are recycled [1].

Because of the importance of these residues, European countries are implementing national and international policies and various procedures aimed to minimize the negative effects of the generation and management of waste on human health and the environment. The waste policy also aims to reduce the use of resources and thus the environmental impact of their production.

Spain has generated in recent years 40 million tons of construction and demolition waste. The 72% of the C&D waste belong to residential construction and the 28% to infrastructure [2]. Therefore, the construction industry, and in particular the construction of residential area, must assume the goal of reducing the detrimental impact that occurs, making it necessary to introduce new procedures to prevent the generation of such waste or new ways for recycling.

In Spain the document that currently regulates the construction and demolition waste at national level is the Spanish Royal Decree 105/2008, of February 1, by regulating the production and management of C&D waste [3]. This Royal Decree studies the following objectives:

- A C&D waste management study will be included in building site projects.
- Separation at source of hazardous C&D waste generated in building site and management according to waste legislation.
- Separation in processing plant of hazardous waste contained in the C&D waste received and management according to waste legislation.
- Separation of the C&D waste in building site, by materials, based on the thresholds established in Royal Decree 105/2008.
- Fulfillment of the Article 13 of Spanish Royal Decree 105/2008, regarding the use (recovery) of inert waste from construction and demolition activities.
- Elimination of uncontrolled dumping of C&D waste. From 16 July 2009 all landfills in Spain must fulfill the requirements of Spanish Royal Decree 1481/2001.
- Treatment of C&D waste by authorized agent under the terms established by law.

This Royal Decree is a main point of Spanish policy on C&D waste and is expected to contribute to sustainable development in such an important sector for the Spanish economy as it is the construction sector.

1.1.- Mineral fibers used in construction

Textile materials can be classified according to their nature into three main groups, natural, artificial or synthetic (Table 1). Fibers that form natural tissues are positioned in a chaotic and irregular way, and therefore, they lose strength. However, fiber molecules can be assembled very tightly in artificial or synthetics tissues, improving its durability and cohesion.

Mineral fibers can be natural, such as asbestos or they can also be extracted too from materials such as glass or some metals. Mineral wool is made from these mineral fibers.

NATURAL FIBERS	MINERAL FIBERS	NATURAL FIBERS	AMIANTO	
		TRANSFORMED FIBERS	FIBERGLASS	
			MINERAL WOOL	
			METALS	GOLD
	VEGETAL FIBERS (CELLULOSE)	SEED FIBERS	COTTON	SILVER
		STEM FIBERS	LINEN	COPPER
		LEAF FIBERS	HEMP	
			ESPARTO	
	ANIMAL FIBERS (PROTEINS)	WOOL		
		SILK		
		LEATHER		
CHEMICAL FIBERS	ARTIFICIAL FIBERS	CELLULOSIC FIBERS	NITROCELLULOSE	
			CUPRAMMONIUM	
			VISCOSE	
			ACETATE	
			TRIACETATE	
		PROTEIN FIBERS	ANIMALS	
			VEGETABLE	
		KELP	RAYONES	
			ALGINATE	
	SYNTHETIC FIBERS	OBTAINED BY POLYCONDENSATION	POLYAMIDE	
			POLYESTER	
		OBTAINED BY POLIMERIZATION	ACRLYLIC	
			POLYVINYL FIBERS	
			POLYETHYLENIC	
			POLYPROPYLENE	
			POLYURETHANE	

Table. 1 "Classification of fibers according to their nature"

Mineral wool is a flexible material composed of inorganic fibers. The wool is made of an interlacing of filaments of stone materials which form a mat which contains and keeps the air in stationary state. They are obtained by foundry, centrifugation and other treatments and they are used in construction and as thermal and acoustic insulation. This material is different from other insulation materials because it is a fire resistant material, with a melting point that exceeds of 1.200 ° C.

There are two types of mineral wool used depending on the feedstock, glass wool obtained from glass and rock wool obtained from basalt rock. Both wools are sold in multiple formats, they are mainly shown in panel form, rigid or semi-rigid, linked with different types of resins such as phenolic resins, fireproof or thermosetting, with or without coating. These coatings can be very different, some of the most used are: aluminum foil, elastomeric film, polyester film, polyethylene kraft paper, plasterboard, bitumen layer, intumescent polymer layer, etc. They can also be found supplied in roll form or in bulk.

Because wool is made of basalt, some manufactures, for example, Rockwool, claim that therefore it is a 100% natural product recyclable and ideal for the development of

sustainable construction projects [4]. Moreover, other manufacturers, e.g. Isover, claim that mineral wool can be used to create new wool, in particular this manufacturer shows the following recycling rates: 66% of wool production surplus and 75% wool glass production surplus [5]. It also incorporates recycled glass in the manufacturing process of the glass wool.

However, both mineral wools need large amounts of energy to manufacture so it is interesting to look for another ways for the wool production surplus and for the C&D waste as the latter do not undergo any process of recycling, reuse and recovery.

Among the mineral fibers used in construction is fiberglass. Fiberglass is easily obtained from the glass, by heating and stretching it with metallic pliers. This fiber is marketed as raw threads of different lengths for the reinforcement of concrete, mortar or plaster. It is also marketed as a composite material in multiple formats such as, acoustic tiles, plasterboard plates reinforced or reinforced asphalt sheets. There are five groups:

- Type E: is the most widely used type of fiber is characterized by its dielectric properties, representing 90% reinforcement for composites.
- Type A: is characterized by having very good mechanical performance, used in aviation, aerospace and armaments.
- Type D: its main feature is its excellent dielectric power of this application in radar, electromagnetic windows...
- AR Type: has a high content in zirconium oxide, which gives it good resistance to alkalis.
- Type C: is characterized by high resistance to chemicals.

2.- Background

The fibers are used since antiquity to reinforce brittle materials such as mud, adobe or tapial. In general, the fiber reinforcement acts to improve the physical-mechanical behavior of the matrix. The behavior of these compound materials depends, firstly, on the type of fiber added, and then on other factors such as percentage of fiber, fiber length, orientation, surface of the fiber.

Several references have been found on the addition of natural-fiber into plaster reinforcement [6] [7] [8] but there are not references about fibers that have been recycled. Cellulose, sisal and hemp are the most common used fibers, but the one that showed better results was sisal fiber [9].

As to the addition of synthetic and mineral fibers in a matrix of plaster, numerous references have been found on the addition of polymeric fibers [10] and glass fibers [11] [12], none of them came from recycling. These fibers are most suitable as the rest are too expensive and have very superior mechanical properties of the plaster. Furthermore, glass fibers are the most commonly used fibers as reinforcement in the prefabricated plaster.

There are many studies which focus on the incorporation of recycled aggregates in construction. These aggregates are added to concrete, mortar and asphalt replacing natural aggregates, with applications in: bases and subbases of road pavement, fundamentally. [13] [14].

Moreover, there are some studies about recycling of expanded polystyrene waste [15] or industrial waste [16] [17], incorporating them as fillers in binders.

One of the industrial wastes with applications in the field of construction is the rubber from used tires. Several documental references have been found on research projects that use the rubber granules as another component in the manufacture of concrete, replacing partially fine aggregate or gravel. [18].

It is considered that although some references were found on the addition of C&DW in a plaster matrix, such as cork recycling [19], no references have been found to the use of mineral fibers from recycling in clusters, particularly in a matrix plaster.

3.- Objective

The main objective of this study is to analyze the viability of recycling fibers obtained from mineral wool from the C&D waste as an alternative material to chopped glass fibers that are currently used as reinforcing elements in the prefabricated plaster.

4.- Experimental Method

Specimens are made of different dimensions 4x4x16 cm using the following materials: plaster E-35, rock wool from the recycling, glass wool from the recycling and E-fiber glass 25mm.

In an initial reference phase, series are made of E-35 plaster and a relation W/ P 0.6 additivated with glass E-fiber (25mm) in the following percentages of addition, 1%, 1.5%, 2%, 2.5%, 3%, 3.5% and 4%.

In the second phase, plaster series are made of E-35 plaster and a relation W/ P 0.6 additivated with rock wool and glass wool from recycling, both in powder form, in the following percentages of addition, 1%, 1.5%, 2%, 2.5%, 3%, 3.5% and 4%. These series are made with mineral wool in powder form because they are recycled blankets with resins, so it is not viable format to incorporate them in fiber form.

On these series, mechanical tests are made to determine the resistance to bending and compression of the specimens and the test to determine the Shore C hardness surface. All of these tests are made according to Spanish UNE EN 13279-2.

5.- Results and Discussion

Different behaviors are analyzed in terms of surface hardness, flexural strength and compressive strength of the plaster additivated with mineral wool from recycling, comparing these results with those obtained for the specimens of plaster additivated with E-fiberglass (25mm), according with different adding percentages.

5.1.- Hardness shore C

It can be noted that for all the percentages of addition, the values of surface hardness obtained are higher in the series with rock wool from recycling. The biggest difference is found for an addition rate of 2%, at this point the series additivated with rock wool with exceed in a 14% to the ones additivated with fiberglass.

For addition rates of 1% and 1.5% the difference is at 12%. From the addition of 2.5%, values are gradually equal and they remain very similar up to the 4% addition studied (fig. 1).

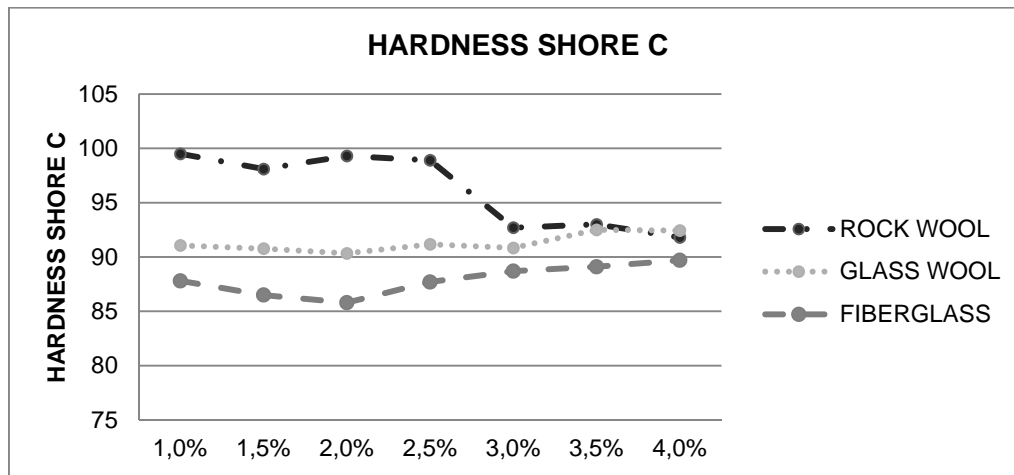


fig. 1 "Comparative C Hardness Shore C"

The series additivated with glass wool also obtain values over the ones additivated with fiberglass for all the addition percentages studied. In this case the results are very similar, the main difference is a 5%, for the percentages of addition of 1.5% and 2%.

5.2.- Flexural strength

Plaster specimens additivated with rock wool obtain lower values for all the percentages of addition than the ones additivated with fiberglass. The values go up until they reach the highest for the 2.5% of addition, at this point the difference from the series additivated with glass fiber is a 16% (fig. 2). The nearest value between these two additions is at the 1% of addition, at this point the difference is 3%. At the other extreme is the addition of 4%, which shows a 50% of difference, the maximum.

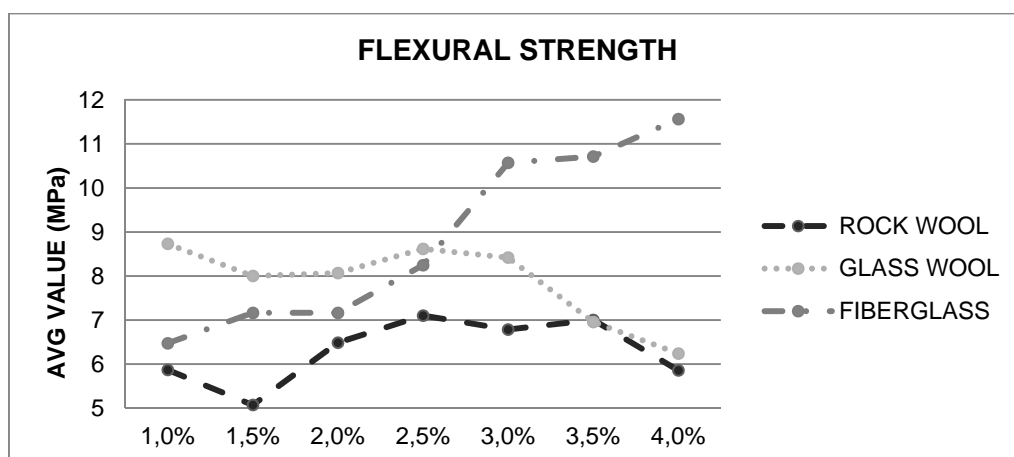


fig. 2 "Flexural strength comparison"

The flexural strength values of the series additivated with glass wool are superior to the ones additivated with glass fiber for the addition rates of less than 3%, obtaining for the 1% of addition a value 26% higher. From 3% of addition the values of the

series additivated with glass wool fall while the ones additivated with glass fiber increase, reaching their maximum difference, 45%, for a 4% of addition.

5.3.- Compressive strength

The series additivated with glass fiber obtain lower compression strength than the ones additivated with mineral wool residue for all the percentages of addition. For rock wool the biggest difference appears for 3% of addition. In this one, the series additivated with rock wool residue exceed in 36% to the ones additivated with fiberglass. There are two peaks at 1.5% and 4% of addition which should be studied (fig. 3).

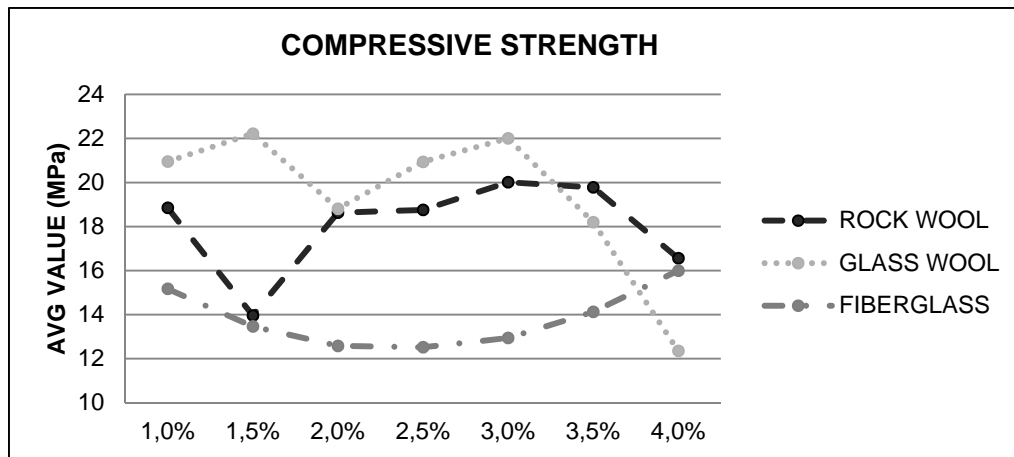


Fig. 3 “Compressive Strength Comparison”

The compression strength values also are lower for the series additivated with glass fiber compared to the series additivated with glass wool residue. This difference can be found between the 33% of addition to a percentage of 2%, and 41 %, for an addition rate of 3%. From 3% of addition, the values descended for the series additivated with glass wool while the values increase for the ones additivated with glass fiber; becoming latter 22% higher, with a 4% of addition.

6.- Conclusions

From the results it is concluded that, with rock wool residue, increases Shore C hardness and compression strength in all of the percentages of addition. However, lower values are obtained for flexural strength in all the percentages of addition.

With regard to the series additivated with glass wool residue is concluded that the surface hardness improves lineally around 5% for all the percentages of addition, with regard to the series additivated with fiberglass. The values of compression strength are superior up to all percentages of addition, except for the 4%. The flexural strength values are superior up to 3% of addition.

As a final conclusion, it can be noted that the series additivated with mineral wool from recycling, show better results in tests that the ones that use fibers used as reinforcement plaster nowadays, so it is viable their replacement. Therefore, the replacement of E-glass fiber with recycled mineral wool is viable.

7. Future research

Research proposed in the future: use of higher percentages of addition, research about the addition other formats of mineral wool, work with other types of tissue from the C&D waste or other mixed industrial waste, mixtures of different types of fibers.

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